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Eagle Island Wetland Mapping Using Satellite Imagery and Bathymery

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Abstract: ***Wetlands are ecosystems characterized by low drainage quality, slow moving water or sometimes standing water body that is filled with soil (Olalekan, Abimbola, Saheed, & Damilola, 2014). Wetlands are a vital part of our economic future and are among the earth's most productive eco-system. The natural ability of wetlands cannot be overlooked in as much as land areas are needed because the wetland complements other physical environmental activities such as runoff draining, carbon sinks, ground water filtering, etc. needed for the sustenance and use of the land by man. Therefore, the mismanagement of wetlands could result in disasters and hinder sustainable development. Irrespective of these facts, the Eagle Island wetland may be threatened by urban development due to the resultant effect of lack of research and control to their conversion, irrespective of the sizes as well as unavailability of spatial and topographic information of Eagle Island. Wetland mapping is key to the enhancement and management of the wetlands and boosts environmental sustainability in the midst of pressures from urban development. The aim of this study is to produce maps of Eagle Island that depict the changes in the wetland areas, flow patterns and bathymetric charts. The study analyzes land cover /land use changes (LCLU) using SPOT 5 and SENTINEL 2A satellite imageries for two epochs, 2005 and 2016 respectively. The satellite images covering the study area were acquired and analyzed using ArcGIS10.3, and ENVI 5.0. Surfer 10 for contour and vector map generation and SDE 28s for processing bathymetric data acquired on the adjoining estuary. The total area analyzed was 224.87hectares. The maximum likelihood method of classification adopted produced four (4) feature classes; Built-up, Water body, Wetland, Sand dunes. The results were validated using the Kappa Index of Agreement (KIA) yielding values of 0.83 for 2005 and 0.98 for 2016. About 20.5% of eagle island wetlands have been lost between 2005 to 2016. The study concluded that there is need for wise use of wetland resources within the study area and recommends the regular mapping of wetlands to avoid indiscriminate conversion of wetlands. Remote sensing methods for wetland mapping and impact assessment should be the basis for planning and decision making in all regions.***

Keywords: Wetland, Mapping, Satellite Imagery, Bathymetry

1. Introduction

Wetlands are a vital part of our economic future. Their natural capabilities serve as solutions to challenges that result from unplanned activities of man, hence they augment livelihood of mankind. This fact has resulted in an increase in the awareness of the natural properties of this natural resource. On another view, the wetland is one of the major constraints to site development, hence the regulation and use of this natural resource to proffer positive solutions towards national development of any region has become critical. Obviously, this is because though it's a natural resource, its mismanagement can result in disasters and therefore hinder sustainable development. It is on this premise that the Ramsar Convention aims at the wise use of all wetlands through local, national and international actions and cooperation as a contribution towards achieving sustainable development all over the world. The Ramsar Convention is an international treaty named after the city of Ramsar in Iran where the treaty was signed in 1971.

The Ramsar Convention states that wetlands include all lakes, rivers, underground aquifers, swamps, marshes, wet grasslands, peat lands, oasis, estuaries, delta's and tidal flats, mangroves and other coastal areas, coral reefs and all man-made sites such as fish ponds, rice paddles, reservoirs, and salt pens. (International Wetlands Authority)

There are various definitions of wetlands which mostly relates to the aim of the research or the type of wetland under study. Wetlands are ecosystems characterized by low drainage quality, slow moving water or sometimes standing water body that is filled with soil (Olalekan, Abimbola, Saheed, & Damilola, 2014). A wetland is also said to be an area where water covers the soil or is present either at the surface or near the surface of the soil all year round or for varying periods of time during the year even during the growing seasons (Zedler & Kercher, 2005). The most common features of all wetlands are the presence of hydric soils, hydrophytic vegetation and hydrologic conditions. These features have field indicators as available in the wetland delineation manual (Zedler & Kercher, 2005). The hydrological features of the wetland are the most important element that defines the type of wetland and aids the functions which include: Improvement of water quality, Nutrient Cycling, Recharging and discharging ground water, Sediment Control, Flood control and Wildlife Habitat maintenance. The relative ability of a wetland to alter flood flows within a watershed and hence control flooding depends mainly on:

a) The size of the wetland relative to the watershed size
b) The spatial relationship to other wetlands
c) The rate of urbanization and infrastructural development.

The focus here is to ascertain the size of the wetland of the study area and the amount of loss experienced in recent times as well as study the terrain topography to ascertain the direction of flow of runoff on Eagle Island in relation to the topography of the adjoining riverbed.

2. The Study Area

The study area is called Eagle Island in Port Harcourt City Local Government Area of Rivers State. It lies within the following longitudes and latitudes: 4° 47' 13".24N, 6° 58' 21".95E, 4° 47' 12".77N, 6° 59' 12".29E, 4° 46' 32".57N, 6°

59' 14".30E and 4° 46' 33".49N and 6° 58' 30".47E as shown in figure 1.1 below. Eagle Island is bounded at the North by the Rivers State University, at the West by Ogologo River (an estuary flowing into the Bonny River), at the East by Diobu community, and at the South by Kidney Island.

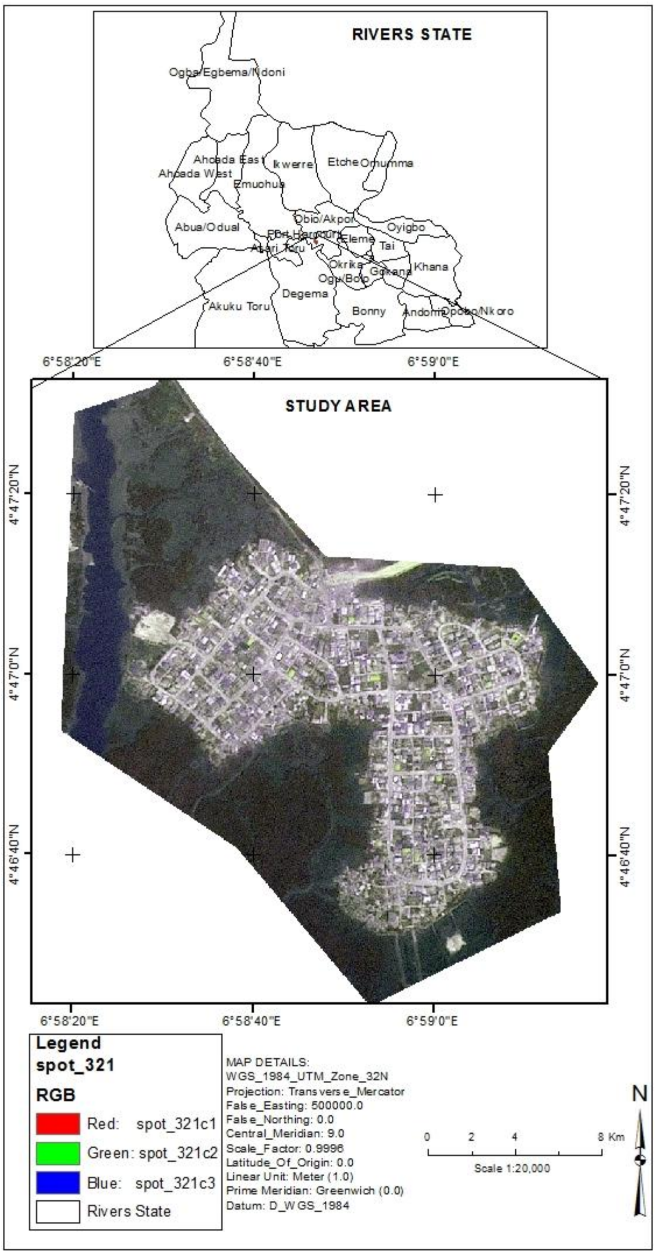


Figure 1.1: Map of the Study Area

Aim of the Study

The aim of this study is to produce maps of Eagle Island that depict the changes in the wetland areas, flow patterns and bathymetric charts.

Step-by step approach to achieving the aim

The aim of this project can be achieved through the following:

1) Determination of the size of the wetland within the study area.
2) Evaluation of the Spatio-temporal wetland changes within the study area over a specific period.
3) Determination of the flow direction on the terrain, from topographic field data and derived Digital Terrain Model (DTM).
4) Determination of the depth of Ogologo river using Echo sounded field data.

3. Literature Review

Importance of Wetlands

The signing of the Ramsar Convention in 1971 gave credence to the importance of wetlands ecosystem services and this has continued to gain momentum worldwide. (Felix et al, 2017). Wetlands are natural productive ecosystems that have great biodiversity. Many regulatory bodies allow the filling of small wetlands and even go further to exempt them from conservative ratings, such that, these wetlands receive lower levels of protection. On the contrary, the loss of small wetlands is one of the most cumulative impacts on wetland (Tuner, 2000). Mitch & Gosselink (2000) declared that when less than 10% of a watershed is a wetland, higher peak storm water flows will occur. The percentage needed in a watershed to maintain these services can vary significantly depending on factors such as wetland type, size, topography, and area of the country (Mitch & Gosselink, 2000).

The importance of wetlands is so crucial to the sustenance of man and his environment. One of the primary causes of Global Warming; the burning of fossil fuels, releases carbon into the atmosphere. The carbon emitted could be absorbed by the presence of wetland vegetation. Consequently, if the wetlands are continuously reclaimed, or destroyed it leaves no other situation than reduction in the absorption of carbon dioxide for plant growth and reduction in the production of oxygen for human development.

Wetland Loss

Wetland loss is an Environmental concern and has been a challenge to nations in terms of the degradation of its natural ability which will hinder economic and sustainable development. Wetland losses began to be much clearer when the negative impact of human disturbances on the functions of the wetlands were separated. The impacts resulting from changing the physical structure, the amount of water, the fluctuation of water levels, the amount of incoming sediment, and changing the acidity of the soils or water as well as introducing toxic contaminants, and fragmenting the wetland habitats, results in loss of wetland. (Sheldon, Leigh, & Kingsford, 2005). In 2014, Bassi stated that the consequences of eliminating wetlands is extinction of sea animals and deteriorating water quality (as cited in Israel et al, 2018). The global trend in the conversion of wetlands for other uses has deleterious effects on surrounding ecosystems and there is a resultant increasing need for the conservation and preservation of wetlands. (Hiestermann, 2015). Most countries have begun to devise ways for which their wetlands could be effectively managed alongside the physical developments in the locations where the wetlands are situated. The US National Wetland Inventory utilizes high-altitude photography to map wetlands in the Unites States, this is because wetland maps are pre-requisites for wetland inventory, planning, management, protection, and restoration. (Wilen, Virginia, & Jones, 2002).

The National wetland Inventory produced highly detailed wetland maps covering 40% of forty-eight (48) states and 10% of Alaska. This was done to develop the inventory of their wetlands towards classification in view of development planning. A documentation of wetland losses and causes for the losses was also done. The purpose was to aid decision makers identify where the pressure of development takes a greater toll on the wetland using statistical approach after identifying areas experiencing drastic growth in urbanization.

Davidson (2014) considered the long term and recent trends associated with wetland areas. He employed the information derived from satellite imageries to make analyses on the amount of the wetland that has been lost.

Benefits of Wetland Restorations

Wetland maps are pre-requisites for wetland development planning, protection and restoration (Felix et al, 2017). The benefits associated with the restoration of wetlands to land owners include the reduction of negative impacts of drought and flood by retaining run-off water, ground and surface water quality is increased, watershed sedimentation is reduced because soil erosion is reduced. There will be reduction in the amount of greenhouse gases and carbon dioxide emissions in the atmosphere, because of their absorption by the restored wetland, thereby increasing terrestrial sequestration. In otherwards, the restoration of wetlands will create a livable environment, reduce flood disasters, maintain water quality and on the whole preserve human wellness (Israel et al, 2018).

Wetland Legislations

(Maureen & Ngozi, 2016) examined the existing legal framework for the protection of wetlands in Nigeria with a view to identifying gaps and deficiencies in the laws. They found out that the existing legislations were inadequate, and so proposed that a vibrant legal framework should be established to ensure healthy and sustainable use of wetlands within the country. In Washington DC, there are no specific natural wetland laws, but the wetlands are managed under regulations related to both land use and water supply. In 1985 and 1990, farm bills under the conservation reserve and wetlands reserve programs - two incentive approaches for the protection and restoration of wetlands were introduced in the United States (EPA, US 2008).

10% of Uganda's land area (205,317km^2) is covered by wetland as indicated by John (1998), in his research work "The Evolution of Policies and Legislation on Wetlands in Uganda". Prior to the wetland protection policy in Uganda, wetlands were the first targets as population increased tremendously. Rich farmers acquired leaseholds upon these wetlands and commenced draining them for dairy farm usage. This gave rise to the emergence of unplanned slums in Kampala.

Satellite Remote Sensing in Wetland Mapping

To conserve wetland resources, manage wetland programs, and evaluate performance of existing programs, it is important to identify and monitor wetlands and their adjacent uplands. Satellite remote sensing data, especially free remote sensing data have many advantages for wetland monitoring. Comparing ground survey and aerial photography, Ozesmi and Bauer in 2002 stated that satellite remote sensing data are relatively less costly and less time-consuming to acquire and use, especially for the analysis of large geographic areas (as cited in Yue Gu, 2015). Brivio in 2002 also stated that the digital format of remote sensing data makes it easy to integrate into the Geographic Information System (GIS) (as cited in Yue Gu, 2015). Satellite can regularly monitor wetland conditions, for instance, Landsat-7 sensors overpass and monitor the same area every 16 days.

Oluwagbenga, Raphael, & Momodu (2009) in their study, "Geospatial Mapping of Wetlands Potential in Ilesa, Southwestern Nigeria", assessed the ecological and socio-economic effects of wetlands. They were able to do the assessment from the mapping of the wetlands trends from 1986 to 2008 using data generated from Landsat imageries of three epochs (Landsat TM 1986 and 1991 and ETM+ 2002). At the end of the classification in GIS environment it was discovered that most of the wetland's degradation was due to agricultural activities and settlement. The study concluded that unless action is taken positively to influence the activities of people affecting wetlands, the consequences could be very serious.

The Akagera wetlands in Rwanda, East Africa were also monitored using remote sensing methods. Felix et al (2017) concluded that to prevent further loss of wetlands and to conserve existing ones, it is paramount to monitor wetlands and their adjacent islands. This assertion was based on results obtained from the mapping of the wetlands from satellite imageries; Landsat 1987 to 2015 at five (5) year intervals, obtained during the dry seasons. The wetland was delineated and their dynamics over time analyzed using the Shuttle Radar Topographic Mission (SRTM) digital elevation at 30m resolution. The results showed that while the extent of the wetland has apparently remained stable, the extent of inhabiting water bodies has been subject to considerable fluctuations over the years. Hence, the findings single out the great necessity of frequent and improved monitoring initiatives to provide timely information and enhance protection mechanisms' efficiencies. (Felix et al, 2017).

Allan (2016) did a review to ascertain updates related to identification of wetlands using remote sensing approach. Advanced Space Borne Thermal Emission Radar (ASTER) and System Probatoire L'Observation de la Terre (SPOT) imageries as well as Sentinel were proposed data for wetland identification/delineation. The advantages of Sentinel over Landsat were discussed as well as the increased number of spectral bands. Sentinel possess Synthetic Aperture Radar (SAR) and reflects energy in the microwave region, hence it is not affected by cloud cover. Radar waves interacts with the land surface to reveal information on three-dimensional structure (Allan 2016).

A recent study was done in Kwazulu-Natal Province of South Africa where remote sensing approach was used to appraise the spatial pattern of the wetlands, potential determinants and effects of wetland depletion from 1987 to 2017. Satellite imageries (1987, 1997, 2007 and 2017) of

Isimangaliso wetland were acquired from USGS database. Band combination involved the Near Infrared (NIR), Short Wave Infrared (SWIR), Thermal Infrared (TIR), and visible bands. The maximum likelihood classification method was used to classify the features (vegetation, built-up, open area, rocky surface). Normalized difference water index (NDWI) revealed that the wetland was experiencing reduction in the water content.

Again, Dienye, Fubara and Pepple (2018), discovered that from 1984 to 2014 the wetlands in Port Harcourt Local Government Area had reduced from 10.905 hectares to 3.136 hectares. They mapped using satellite remote sensing data to monitor wetland depletion within the study area using satellite imagery for the enhancement of wetland management and Environmental Sustainability in the midst of urban development. It was also discovered from the Land Use/ Land Cover Maps derived from supervised classification of raster data that the wetlands were lost due to reclamation activities.

Bathymetry of Wetland Areas

Bathymetry is the measurement of underwater topography. The depth of the water body (sounding measurements) and positions of underwater features are results obtained from bathymetric surveys.

There are various instrumentations employed for hydrographic surveys, such as multi and single beam eco-sounding methods, single beam methods, Acoustic Doppler Current Profiler (ADCP), Sub-bottom Profiler, Eco mapper Autonomous Underwater Vehicle (EAUV). (USGS Report, 2017). A multi-beam echo sounder attached to a boat, sends out a wide array of beams across a water body floor. As the beams bounces back from the river floor, the data is collected and processed. The single beam echo sounder on the other hand measures water depth directly under the boat. They are generally used for smaller water bodies. The ADCP,s measure water velocity by transmitting sound waves which are reflected off sediment and other materials in the water. The EAUV collects detailed bathymetric data in places that are difficult to reach with boats. It uses side-scan sonar and a Doppler velocity log. (USGS Report, 2017).

In wetlands, developing bathymetric charts can have many applications including determining the storage capacity and hydro period (depth and timing of flooding) of a wetland, assisting with the wetland design and restoration and land use planning as well as facilitating legal boundary determination (Huertos & Smith, 2013). Wetland bathymetry influences residence time, flood retention, sediment trapping (Gallardo, 2003; Takekana et al, 2010). With adequate bathymetric charts we can develop a description of the dynamic changes in wetland conditions.

From the foregoing, although researches on wetlands have been carried out based on the increasing awareness about the importance of these natural resources, yet in developing countries of which Nigeria (the domain of the study area) is inclusive, their protection and restoration are yet to be taken seriously. The agencies responsible for the preservation of wetlands are yet to be singled out and the laws are not specific. The lands are vested in the hands of the government but the factors and expertise needed for the management of these wetlands have been ignored. In addition, the data and information derived from mapping within the study area are found to be scarce.

4. Methodology

Satellite Remote Sensing

The use of Earth Observation Satellites provides reliable and standardized sources of environmental data. Satellite Remote Sensing approach was employed for this study. The reason is not farfetched. This approach has advantages that suit the prevailing challenges in the locality. Remote sensing is the acquisition and measurement of data/information on some phenomena, object or material by a recording device that is not in physical or intimate contact with the feature under surveillance. It is the branch of applied geomodelling science that deals with the representation, analysis, and measurement of the characteristics of features of object, scenes or phenomena with the use of sensors that are not in physical contact with the object, but can record and analyze signals from the target objects. The Canadian Center for recording reflected Remote Sensing (CCRS) defined remote sensing as the science (and to some extent, art) of acquiring information about the earth's surface without actually being in contact with it. This is done by sensing the emitted energy emitted from the earth's surface and thereafter, processing, analyzing, and applying that information. The advantages of overcoming inaccessibility and rather slow contact methods, historical image record and change detection documentation ability, and the anonymous approach were considered appropriate for the study.

System Requirement

In analyzing change in wetland zone in the study area, the following software and hardware were utilized, namely:

a) ESRI's ArcGIS 10.3 for the clipping of images used in the study, modeling watershed, and compilation of maps.
b) Surfer 10 for contour and vector map generation
c) ENVI 5.0 software for Raster processing.
d) SDE-28s software for processing hydrographic data.
e) Microsoft Office Document

Instrumentation

1) Total Station (TS02-7)
2) South Echo sounder and accessories

Some hardware components were integrated in the study and they include a set of Laptop computer with processor Intel® Core (TM2) Duo CPU P9700, 4.00GB RAM, and 64-bit operating system. The laptop consists of keyboard, mouse, and all installed applications program including Microsoft excel for statistical models. The computer configuration was selected such that the applications, especially, remote sensing software can be installed easily. An external (1TB) hard drive for data storage was a supporting hardware device used during the period.

Data Sources and Characteristics

Data acquisition is a process of identifying and gathering data required for an application. The acquired data for the study includes:

a) SPOT 5 Satellite Imagery
b) SNAP- Sentinel 2A platform
c) Terrain Spot heights data from spirit levelling
d) Hydrographic data of the adjoining river channel
e) Google Imagery of the Study area

Table 3.1: SPOT 5 Imagery Characteristics

Mode	Band	Spectral band	Resolution
Multispectral	B1	0.50 – 0.59 µm	10m x 10m
	B2	0.61 – 0.68 µm	10m x 10m
	B3	0.78 – 0.89 µm	10m x 10m
	SWIR	1.58 – 1.75 µm	20m x 20m
M – mono-spectral	PAN	0.51 – 0.73 µm	5m x 5m (or 2.5m x 2.5m in super mode

Source: Satellite Imaging Corporation, 2017(www.satimagingcorp.com)

Table 3.2: SETINEL-2A Imagery Characteristics

Spatial Resolution (m)		Band Number	Central Wavelength (nm)	Bandwidth (nm)
10	Blue	2	496.6	98
		3	560.0	45
		4	664.5	38
	SWIR	8	835.1	145
20		5	703.9	19
	NIR	6	740.2	18
	NIR	7	782.5	28
	SWIR	8a	864.8	33
	SWIR	11	1613.7	143
	SWIR	12	2202.4	242
60	Visible	1	443.9	27
	V/SWIR	9	945.0	26
	SWIR	10	1373.5	75

Source: Park, H., Choi, J., Park, N., & Choi, S. (2017).

Figure 3.1: SPOT 5 Imagery of Eagle Island and environs

Spot Height Data

Leveling was done on the Island to ascertain the height information of various points. The mean sea level height datum of XSV673 of value 3.571meters was transferred with a total distance of 830m to the monumented pillars, with all pillars positioned from the front of River State sewage disposal company to the others with 200m total distance along the access to the study area. The control points used for the levelling are stated in table 3.3 below.

Table 3.3: Coordinates of Control Points

Station	Elevation (m)	Eastings (m)	Northings (m)	DIST. (m)
SVG 2018 001	3.012m	275452.700	530051.864	0
SVG 2018 002	3.467m	275485.235	529994.721	65.57
SVG 2018 003	1.967m	275520.260	529906.313	94.87

Source : Igenewari and Abam-ado 2018

The points were selected and pegged out with nails driven into the ground for safety and easy identification. The spot heights were obtained with the total station (TS-02), and the information obtained overlapped with the bathymetry fixes and positions to give a full topography of both surface and riverbed. A total number of 92 change points around the Island was observed with over 3000 spot height values obtained in 7days. The coordinate system of the values obtained is the Universal Transverse Mercator (UTM), Clark 1880 Datum.

Bathymetry

The sounding of River Ogologo on the Eastern side of the study area commenced immediately after the calibration of the echo sounder. The Digital Echo Sounder with the Global Positioning System (GPS) shows both the depth and its position as at the time of sounding. The sounding started at the Northern part of the River close to the slaughter market and moved Southward with a right-to-left pattern of sounding. The boat was navigated through all the sounding lines, as the Echo Sounder displayed the depths and corresponding coordinates of the sounded point with the help of the GPS. The Echo Sounder automatically saves the data in its memory from the start time to the end time of each sounding line. Fixes of depths was done at 5m interval as the boat moved along the river.

Data Processing

Image Re-sampling

The SPOT 2005 imagery has a spatial resolution of 5m x 5m in the Panchromatic Band and SENTINEL 2A has spatial resolution of 10m x 10m in the visible and Short-Wave Infrared region (SWIR) – refer to tables 3.1 and 3.2. Both imageries are in the same coordinate system; the UTM. The satellite imageries were re-sampled to spatial resolution of 10m x 10m using ArcGIS. The image re-sampling operation was necessary in other to have similar spatial resolutions (ground scale measurement) for all the imageries in the study.

Image Clipping

The first and perhaps the most important task of any research is to define the extent of the study area. The study area was defined using image clipping operation in ArcGIS (Richard, 2015). Image clipping operation restricts the researcher within the scope of study, thereby eliminating unwanted data intruding in the results. Raster clipping was carried out in the ArcGIS Arc Toolbox raster processing tool in the data management. It was carried out by inputting the coordinates of the Northern and lower extent and the output file in the dialogue box. The clipped image was exported in Tag Image File Format (TIFF) to ENVI and here it was resaved in GeoTIFF. The coordinates of the upper and lower extent adopted is shown in table 3.4 below.

Table 3.4: Coordinates in UTM Zone 32N used in the Image Clipping

EASTINGS(m)		NORTHINGS(m)	
UPPER	LOWER	UPPER	LOWER
276892.500	275060.000	530077.500	527710.000

Band Combination

In delineating wetland areas, it is important that the various bands of the acquired imagery are combined. This is simply because the objects in the environment have different spectral reflectance that are visible in either of the bands in the visible region of the electromagnetic spectrum. Image composite is one of the enhancement techniques used in processing remotely sensed image data (Norman et al, 2004). This process enhances visual interpretation of the digital image. Colored infrared images are preferred for image interpretation because they provide high level contrast in the image tone, texture and colour between the wetlands and non-wetlands. Similarly, the reflectance signature of moist soils is more distinct than less moist soils when using colour infrared images (Lillesand et al, 2007). In this study, the colour composite of the study area was performed in IDRISI from the raster processing tool by adding three bands (432) for Sentinel 2A and bands 321 for SPOT into band combination dialogue box. These bands were chosen because band 4 (near infrared) is preferable in delineating interface between land and water (Centre for Biodiversity and Conservation, 2004). The composite images are shown in figures 3.2 and 3.3 below for the two epochs.

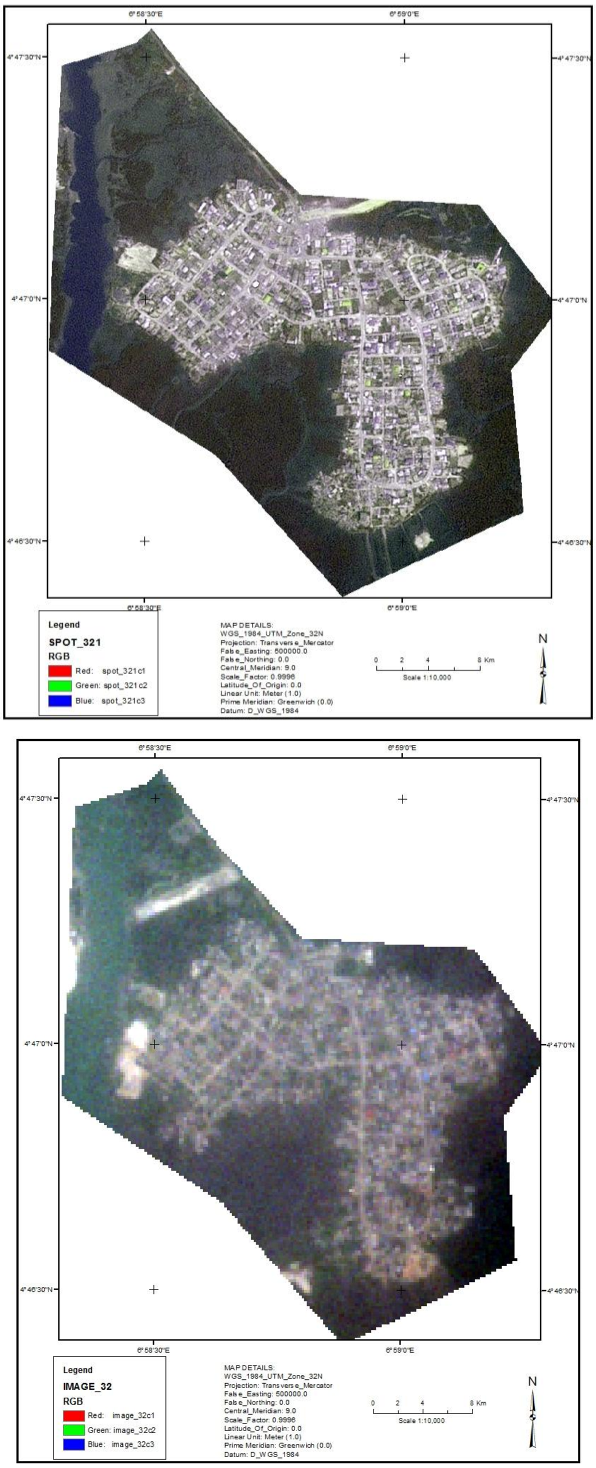


Figure 3.2: Colour Composite of SPOT 5 and SENTINEL 2A ImagerIES of Eagle Island

Image classification and Validation

Image classification is a method of extracting land use and land cover from satellite imageries. It is the process of interpretation and identification of information on remotely sensed image data (Momani et al, 2011). The objective of image classification is to correct/compensate for data errors enhance the image and to rectify the image for further extraction of needed information. This remote sensing technique was used to analyse the composite map resulting in the area for each of the land use/land cover map for the period of study. It involved grouping of the pixels representing the water bodies, the wetlands and the built-up areas within the study area. This resulted in the various datasets including the area of the various land use and land cover.

During image classification level I classification scheme was adopted in which four land cover types (water body, built up, sand dump and wetland) were identified and classified. This study adopted the supervised classification method - Maximum Likelihood approach (MLC), using a vector layer containing training polygons This process was carried out for all the bands of the two imageries, 2005 and 2016 using the ROI tool from the standard tool bar. From the standard tool bar click on "BASIC Tools" - Create ROI tool – ROI tool.

This method identified pixels classes within a specified radius. It is the most frequently used classification method in recent times. The MLC assumed that the pixel is assigned to the class to which it has the highest probability. The operation was performed using ENVI software by creating training site for the features class and the output file name in the MLC dialogue box.

The error generated during the classification process is accessed using the statistical model known as the Kappa Coefficient also called "Cohen's Kappa. (Sim & Wright, 2005). This value is derived from the analyses of the confusion matrix or error matrix, as shown in the sample table 3.4 below, of the two epochs.

Table 3.5: Sample table of error matrix

	Rater (Expected values)			
		1	2	Total
Rater (Observed values)	1	P_{11}	P_{12}	P_1
	2	P_{21}	P_{22}	P_2
	Total	P_1	P_2	1

Source: Sim & Wright, (2005).

The error matrix enables one visualize the performance of an algorithm or a classification model (or classifier) on a set of test data for which true values are known. (Liu, et al, 2018). It contains information about the actual and predicted (probable) classification producing an observed level of agreement, given by *K*. The observed level of agreement or the Kappa Index of agreement, also known as percentage agreement, is given as:

$$K = \frac{P_0}{A} \quad \ldots\ldots\ldots\ldots \quad (1)$$

(Jack, 2017)

Where P_0 is the actual observed agreement, and A is the total chances classified.

$$P_0 = P_{11} + P_{22} \quad \ldots\ldots\ldots \quad (2)$$

Where P_{11}, P_{12}, are the correctly trained feature classes indicating a strong agreement between what was classified and the actual. They are the diagonal elements in the confusion matrix.

For 'n' number of feature classes, P_0 becomes;

$$P_0 = P_{11} + P_{22} + P_{nn} \quad \ldots\ldots\ldots\ldots (2a)$$

Hence the error matrix defined by the four feature classes was used to compare the ground truth data with the results of the classification, will produce;

$$P_0 = P_{11} + P_{22} + P_{33} + P_{44} \quad \ldots\ldots\ldots\ldots (3)$$

The accuracy of the classified imageries is given as;

$$K = \frac{P_0 - P_e}{1 - P_e} \quad \ldots\ldots\ldots\ldots \quad (4)$$

Where K = Kappa Index of agreement

P_0 = sum of the diagonal elements for n- feature classes, and

P_e = expected agreement by chance.

$$P_e = \frac{P_1 P_1}{n} + \frac{P_2 P_2}{n} \quad \ldots\ldots(5)$$

The Kappa statistic is therefore the metric that compares an observed accuracy with the expected accuracy (random chance), being an estimation of the population coefficient.

The kappa coefficient does not reflect sampling error, and where it is intended to generalize the findings of a reliability study to a population of raters, the coefficient is frequently assessed for statistical significance through a hypothesis test. (Sim & Wright, 2005). Hence, a confidence interval around the sample estimate of kappa, using the standard error of kappa and the *z*- score corresponding to the desired level of confidence is calculated. For 95% confidence interval, the z-score is 1.96 for a two-tailed hypothesis for: $0 \leq K \leq 1$.

The value for the standard error of Kappa is given by:

$$SE_K = [P\,(1 - P) / n\,(1 - Pe)^2] \quad \ldots\ldots\ldots \quad (6)$$

Change Detection

Change detection in GIS is a method of understanding how a given area has changed between two or more time periods. Change detection is helpful for understanding the changes in forest coverage, ice sheets, infrastructure development (roads, rails, etc) and land use. Change detection involves comparing changes between aerial photographs taken over different time periods that cover the exact same geographic area. Change detection was done using the ENVI software for two epochs (2005 - 2016) to ascertain the amount of change in wetland area that has occurred.

Digital Terrain Model

A Digital Terrain Model (DTM) provides a bare earth representation of terrain or surface topography. This was obtained using the topographic spot heights obtained during the leveling operation. The results from the on-ground survey could be compared to the elevation obtained from the imageries.

5. Results and Analysis

Presentation of Classification Result

Table 4.1: Classification Distribution Summary for 2005

S/No	Class	No. of points picked	Area (ha)	% Area
1	Built-up	6675	73.91	32.87
2	Water body	4329	14.48	6.44
3	Wetland	10965	127.69	56.78
4	Sand dune	3540	8.79	3.91
	TOTAL	25509	224.87	100

Table 4.2: Classification Distribution Summary for 2016

1	Class	No. of points picked	Area (ha)	% Area
1	Built-up	717	96.25	42.80
2	Water body	293	41.97	18.66
3	Wetland	1095	81.66	36.31
4	Sand dune	1255	4.99	2.23
	TOTAL	3360	224.87	100

Validation of Classification Results

After the digital image classification using MLC, the classification was validated using error matrix (Congalton, 1991) which is integrated in IDRISI TAIGA software. Error assessment of remotely sensed image data classification is essential due to a number of factors such as positional accuracy, inability to train correctly, and the classification method adopted (Lu and Weng, 2007). The error matrix which is also called confusion matrix in some literature, produced Kappa Index of Agreement (KIA) from which accuracy assessment was based. The Kappa coefficient is the difference between the actual agreement and the change agreement (Lentilucci, 2006). The error matrix was performed using the training site as the ground truth image and the classification map as the categorical image.

Figures 4.1 and 4.2 below are the maps showing the results of the Maximum likelihood classification process for 2005 and 2016.

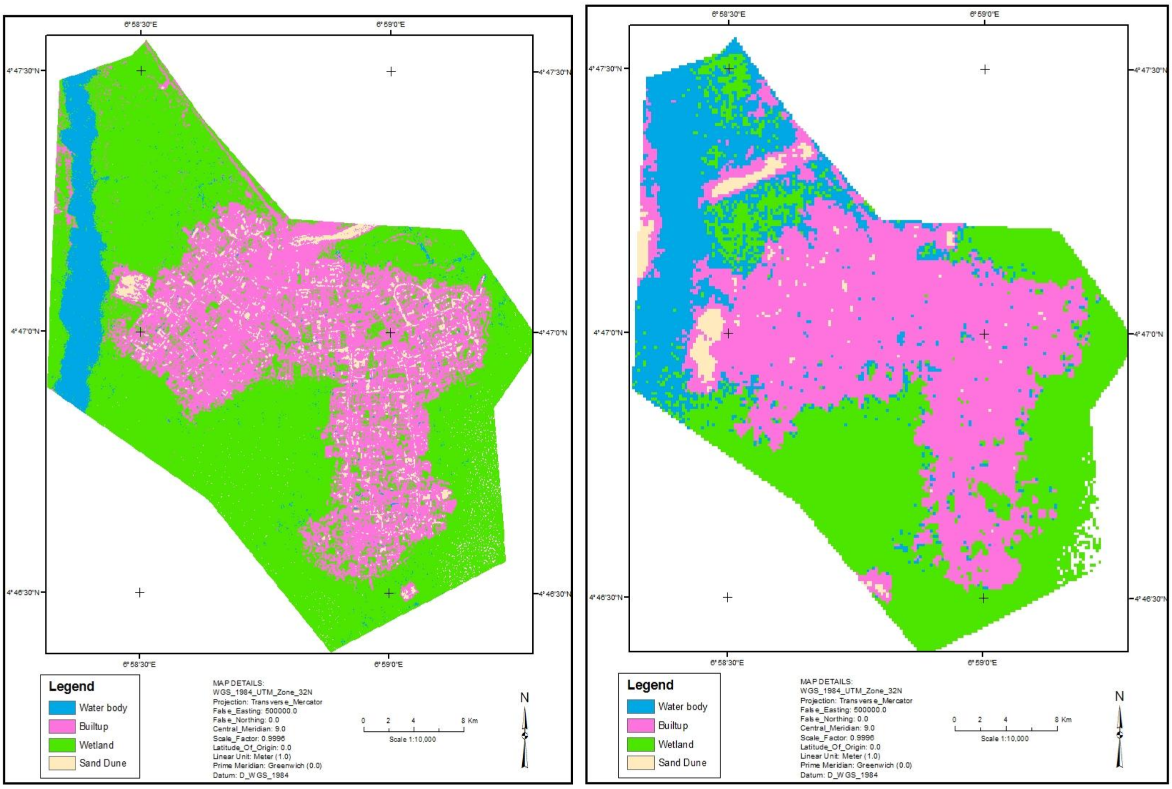


Figure 4.1and 4.2: Map showing the result of SPOT 5 and SENTINEL 2A Image Classification

Confusion Matrices (Pixels)

The confusion matrix was calculated by comparing the location and class of each ground truth pixel defined by the trained area with the corresponding location and class in the classification image. Each column of the confusion matrix represents a ground truth class and the values in the column correspond to the classification image's labeling of the ground truth pixels. See tables 4.3 and 4.4 below.

Table 4.3: Ground Truth for 2005(Pixels)

Class	Water body	Built-up	wetland	Sand dump	Total
Water body	6624	4	127	0	6755
Built-up	0	3444	29	18	3491
wetland	51	75	10809	3129	14064
Sand dump	0	806	0	393	1199
Total	6675	4329	10965	3540	25509

Table 4.4: Ground Truth for 2016(Pixels)

Class	Water body	Built-up	wetland	Sand dump	Total
Water body	710	0	4	0	714
Built-up	4	280	0	16	300
wetland	3	0	1091	0	1094
Sand dump	0	13	0	1239	1252
Total	717	293	1095	1255	3360

Confusion Matrices (Percent)

The Ground Truth (percent) for each class distribution is the percentage value for the ground truth class. The values are calculated by dividing the pixel counts in each ground truth column by the total number of pixels in a given ground truth class.

Commission/Omission

Errors of omission represent pixels that belong to the ground truth class but the classification technique has failed to classify them into the proper class. The errors of omission are shown in the columns of the confusion matrix. Errors of commission represent pixels that belong to another class that are labelled as belonging to the class of interest. The errors of commission are shown in the rows of the confusion matrix. Tables 4.5 and 4.6 show the errors of Commission and omission for the two epochs.

Table 4.5: Commission/Omission for 2005

Class	Omission (Pixels) 2005	Commission (Pixels) 2005	Omission (Percent) 2005	Commission (Percent) 2005
Water body	51/6675	131/6755	0.76	1.94
Built-up	885/4329	47/3491	20.44	1.35
wetland	156/10965	3255/14064	1.42	1.42
Sand dump	3147/3540	806/1199	88.90	67.22

Table 4.6: Commission/Omission for 2016

Class	Omission (Pixels) 2016	Commission (Pixels) 2016	Omission (Percent) 2016	Commission (Percent) 2016
Water body	7/717	4/714	0.98	0.56
Built-up	13/293	20/300	4.44	6.67
wetland	4/1095	3/1094	0.37	0.27
Sand dump	16//1255	13/1252	1.27	1.04

4.2.4 Kappa Coefficient

The reliability of the results obtained is defined by the Kappa Index Agreement (KIA). It is the percentage ratio of the sum of the diagonal values of the confusion matrix to the total pixels of the area. Table 4.7 below shows the precision of the classification given as the KAPPA value.

Table 4.7: Total Area per class of the classification maps and accuracy assessment results

LULC	SPOT 2005 (ha)	SENTINEL-2A 2016 (ha)
Built-up	73.91	96.25
Water body	14.48	41.97
Wetland	127.69	81.66
Sand dune	8.79	4.99
KAPPA	**0.83**	**0.98**

For 2005 we have the following results: Water body has 6624 pixels, built-up contained 3444 pixels, wetlands have 10809 pixels, and sand dump has 393 pixels. The total Land classification shows 25509 counts while overall Accuracy is 83.38% and Kappa Index of agreement Coefficient of 0.83.

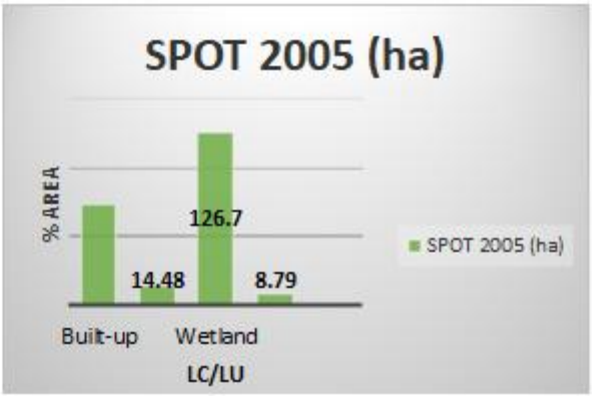
For 2016 we have the following results: Water body has 710 pixels, built-up contained 280 pixels, wetlands have 1091 pixels, and sand dump has 1239 pixels. The total Land classification shows 3360 counts while overall Accuracy is 98.81% and Kappa Coefficient of 0.98.

From the maps of two epochs it is obvious that the wetland has reduced in size especially at the Northern part of the Island. The water bodies are much more distinct indicating increase in water around Eagle Island. In table 4.8 below, the area derived from the study shows that there is an increase of 9.93% for built-up area and a decline of 20.47% in the wetland area between 2005 and 2016. The size of the wetland is 81.66 hectares against at total area of 224.87 hectares. This indicates that there is need for urgent regulatory measures in the use of the wetlands within the Island.

Table 4.8: Land Use/Land Cover change per class in hectares

LULC	**2005**		**2016**		**2005 - 2016**	
	Area (ha)	**% Area**	**Area (ha)**	**% Area**	**Area (ha)**	**% Total Change**
Built-up	73.91	32.87	96.25	42.80	22.34	9.93
Water body	14.48	6.44	41.97	18.66	27.49	12.22
Wetland	127.69	56.78	81.66	36.31	- 46.03	-20.47
Sand Dune	8.79	3.91	4.99	2.23	-3.80	-1.69
TOTAL	**224.87**	**100**	**224.87**	**100**	**0.00**	**0.00**

Graphically one can quickly appreciate the results of the land cover/land use within the study area. (see figures 4.3 and 4.4).



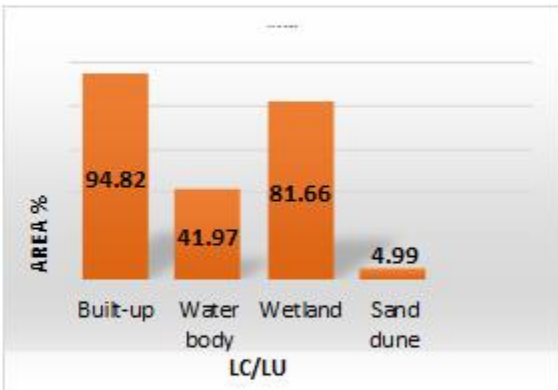


Figure 4.3& 4.4: Bar chart of 2005 and 2016 classification map

Table 4.8, figure 4.3 and figure 4.4 display the Spatio temporal changes in the study area from 2005 to 2016. As the size in the built-up area increases, there is reduction in the wetland area. This points out to the researcher that the wetlands are converted for building houses or other needed structure, especially considering that the percentage omission and commission as stated in table 4.6 above are below 1%.

The field data obtained from the bathymetric survey reveals a depth of about 18 meters, whereas the terrain has highest elevation of about 6.5meters.

4.3 Spot Height Results

Table 4.9 below shows an excerpt of spot height data obtained after the levelling operation in Eagle Island. From the values obtained, the highest points is 6.38m and the lowest points which are close to the wetland zones are. 0. 73m respectively.

Table 4.9: Spot height values obtained from levelling operation

EASTINGS (m)	NORTHENS (m)	HEIGHT (m)
275942.967	529397.171	1.96
275951.523	529400.367	1.88
275958.621	529374.525	2.37
275949.234	529370.948	2.16
275957.448	529368.109	2.25

Water flows from highest to lowest elevations, and as shown in the contour map (figure 4.6), the highest elevation is at two (2) peak points on the study area. Hence water flows towards the areas where the wetland is located as shown in figure 4.8 where the flow direction is superimposed on the Imagery to satisfy objective 3.

From the data acquired, the Spot height Map, the Contour Map and the flow direction maps were plotted. See figures 4.5, 4.6 and 4.7 below. These satisfy objective three (3) and four (4) of this project.

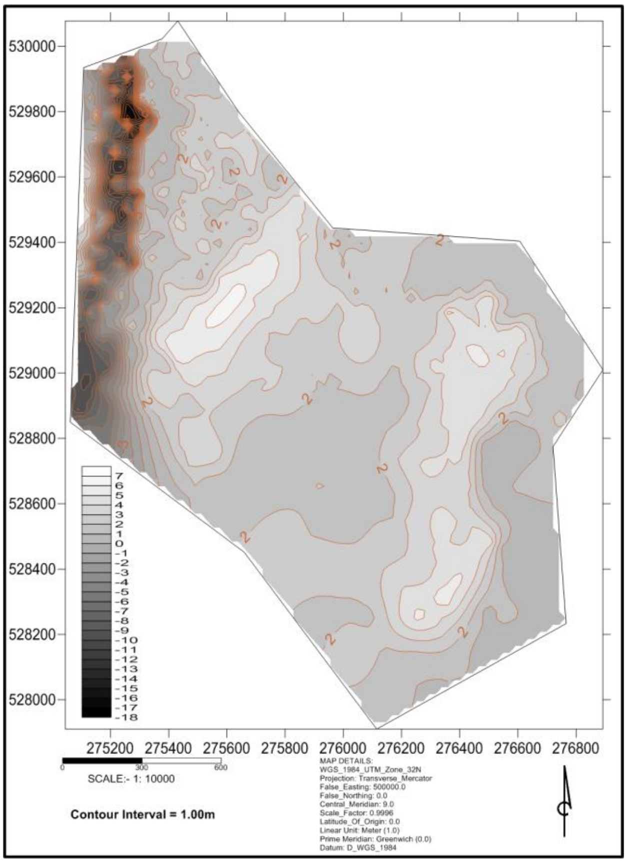


Figure 4.6: Contour Map on shaded relief

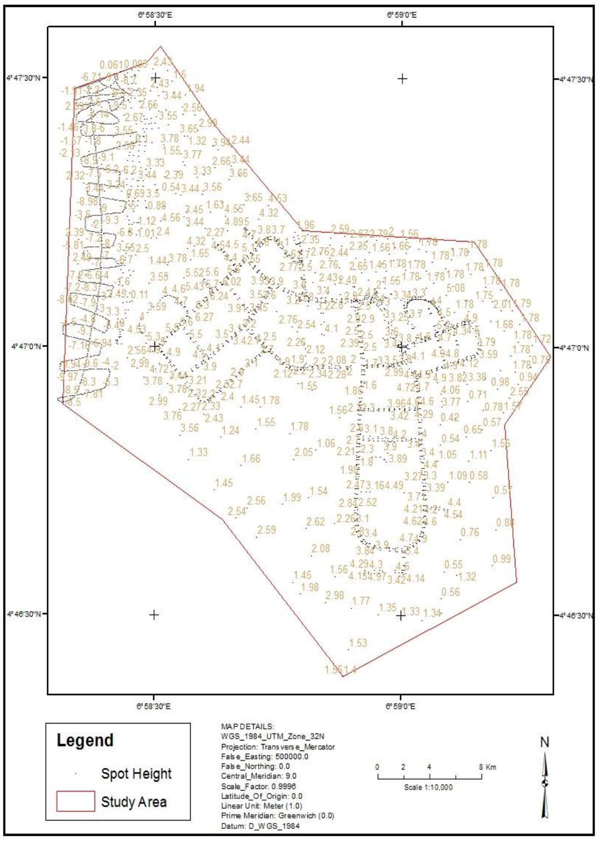


Figure 4.5: Map shewing the Spot heights

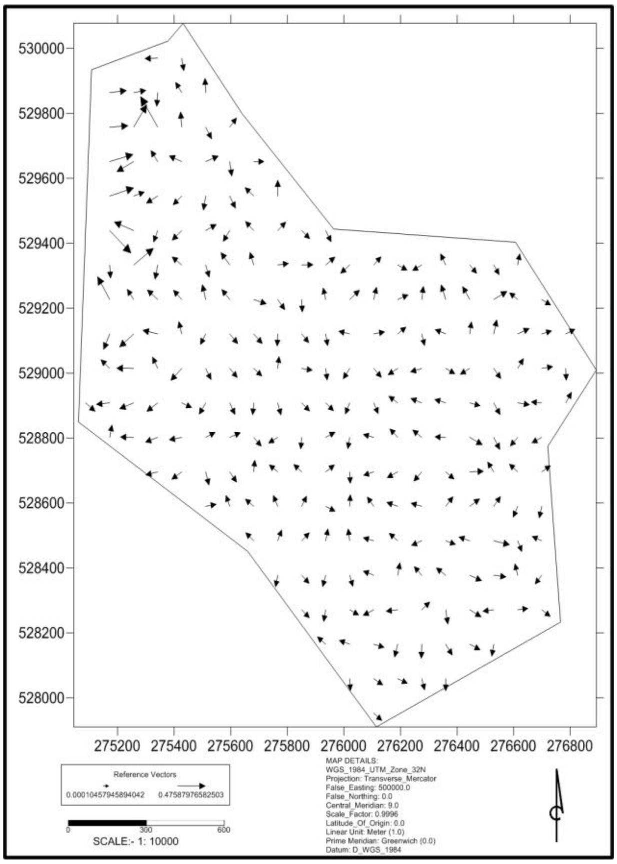


Figure 4.7: Flow direction map of the study area

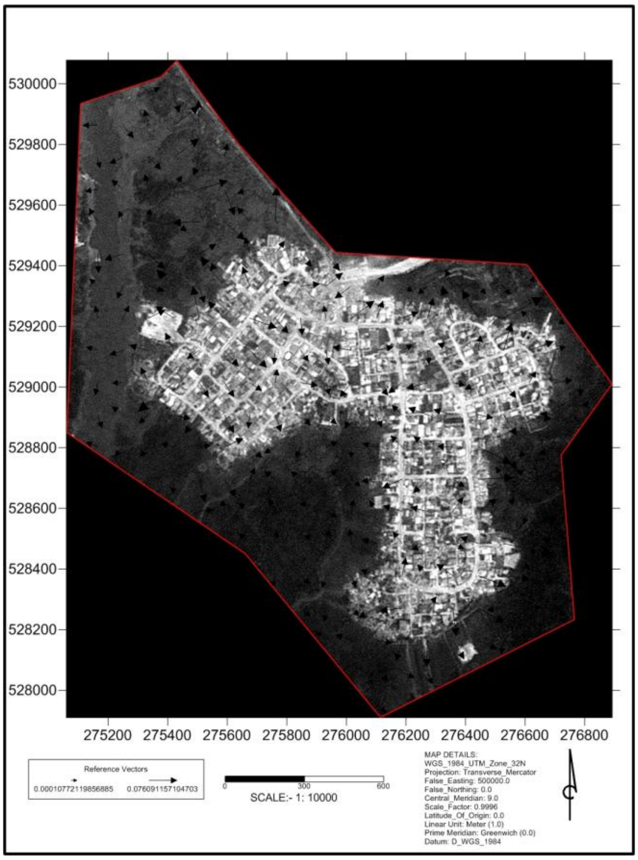


Figure 4.8: Flow direction map overlaid on Imagery

6. Conclusion and Recommendation

The SPOT and Sentinel imageries of 2005 and 2016, were acquired, pre-processed and classified using the ENVI 5.0 software. Four (4) Land Use/Land Cover (LU/LC) types were identified on the satellite imageries within the period under review, 2005-2016. The processed and classified satellite imageries showed the status of the wetlands for the respective years. The wetland configuration in 2005 was then compared with that obtained from satellite imageries of 2016. Reclamation activities were prominent in the study area and played vital roles in degrading the wetlands. There was noticeable degradation of the wetlands within the study area as a result of human activities of infrastructural development. The combination of Image processing technique in Remote Sensing and as well as the GIS software used has proved to be a unique and vital tool in detecting wetland changes over time in relation to economic and social factors. Monitoring this economic natural resource is essential to facilitate proper management.

The application of ENVI 5.0 and ArcGIS 10.3 software ensured that the desired classifications on the imageries were successful. The versatility of the software cannot be overemphasized for wetland studies aimed at delineating boundaries of wetlands in watersheds. The methods adopted ensured that the aim of the study was achieved. The application of satellite remote sensing technology in wetland studies especially along the coastal area is a sure course of action that should be adopted.The size of Eagle Island Wetland is 81.66 hectares as against 127.69 hectares in 2005. About 20.5% wetlands have been lost in Eagle Island from 20015 to 2016. Water flows from the center of the Island (from toe peak points) towards the areas covered by wetlands, where the River Ogologo is situated. The depth of Ogologo River ranges between 0.03m and 18.15m below MSL. The difference in elevation from the land surface to the river bed is approximately 12m (18.15m - 6.49m). The study therefore enabled the production of maps that depict the changes in the wetland areas, show the flow patterns and obtain values for the adjoining River depths.

Based on the study and the results achieved, the following recommendations are made:

1) The reduction in size wetlands even in tidal coastal area should not be overlooked
2) Remote sensing methods for wetland mapping and impact assessment should be the basis for planning and decision making in all regions.
3) This research offers a solution to the challenge of mapping wetlands using conventional survey method. In most cases wetland mapping is overlooked and considered as not necessary.
4) Further studies associated with wetlands should be carried out and the information/data resulting from such studies should be made accessible to the public.
5) The study recommends regular mapping of wetlands to avoid indiscriminate conversion of wetlands to assist in better boundary definition among communities and better-quality images free of cloud cover and haze would allow for a more accurate assessment of land use/land cover, possibly removing most error affecting the classification methods.

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